

Nelson Forest Region	Shelterwood Harvesting in Root Disease Infected Stands in Southeastern British Columbia: Post-Harvest Soil Disturbance - EP 1186 by Harry Quesnel and Mike Curran	
	Extension Note 043	

INTRODUCTION

In 1993, the Forest Sciences Section of the Nelson Forest Region (NFR) designed and initiated a project to test the use of partial cutting in root disease infected areas, and to test the effectiveness and operational feasibility of root disease treatments in both clearcut and shelterwood silvicultural systems. The trial is being conducted at two sites: one site is located near Golden, British Columbia (BC) and is infected with *Tomentosus* root disease; the other site is near Nakusp, BC and is heavily infected with *Armillaria* root disease.

Site characteristics, soil disturbance hazards, and other studies on the two sites are described in Delong (1995) and Nelson Forest Region (1996). Soil compaction is further discussed in Quesnel and Curran (in preparation). While other research is still under way at the study sites, the soil disturbance component of the trial is complete and the results are summarized here.

Pushover harvesting frequently causes more potentially detrimental disturbance than conventional ground skidding plus mechanical site preparation (Davis and Wells 1994). Soil scientists are also concerned that partial-cutting systems may have undesired effects on the soil resource due to greater permanent access requirements, potentially greater length of active roads, and other potential site degrading impacts. Assessment of the impact of these harvesting methods on soil properties may provide support or direction for modifying site disturbance guidelines in the Forest Practices Code (FPC) guidebooks.

SITE DESCRIPTIONS

The Golden site is located on the Mount 7 Forest Service road, 4 km east of town, in the Interior Cedar-Hemlock moist cool (ICHmk1)/ Montane Spruce dry cool (MSdk) subzone transition. Surface soils are predominantly silt loam and loam-textured, calcareous parent material with high pH occurs at 30 to 70 cm depth, and slopes range from 5 to 35%.

The Nakusp site is located on Ice Road, about 50 km south of Nakusp, in the Interior Cedar-Hemlock moist warm (ICHmw2) subzone. Surface soils are predominantly silt loam and fine sandy loam textured with noncalcareous parent materials. The site is north facing with slopes ranging from 25 to 35%.

STUDY DESIGN

- *At two study sites in the Nelson Forest Region, pushover harvesting caused a significantly greater level of counted soil disturbance and forest floor displacement than hand felling combined with ground skidding.*
- *The soil disturbance results support the Nelson Forest Region's soil conservation guidelines for application of root removal on sites that meet the site sensitivity criteria for root removal. The soil disturbance results also support the site sensitivity criteria of the guidelines.*

At each site, eight treatments were established, with two replicates per treatment, for a total of 16 one-ha (100 m x 100 m) treatment units. The undisturbed controls are not of interest for soil disturbance measurements.

Treatments:

1. Hand-felled clearcut
2. Hand-felled light shelterwood
3. Hand-felled heavy shelterwood
4. Control (for conventional)
5. Pushover clearcut
6. Pushover light shelterwood
7. Pushover heavy shelterwood
8. Control (for pushover)

HARVESTING

The Golden site was harvested January to March 1995. Snow depth ranged from 20-35 cm during harvesting. Soils were not frozen except on the main skid trails. Rubber-tired skidders were used in the clearcut treatment units and on the main trails. The shelterwood treatment units were yarded with a crawler-tractor. An excavator was used for pushover falling. Main skid roads were located outside the treatment units and were designated before harvesting. Treatment Unit 14 was accessed by a skid road along the edge of Treatment Unit 13.

Random skidding was used inside the treatment units. Main skid trail rehabilitation, fluffing, and cross-ditching were carried out by the excavator. For the first two pushover treatment units, whole trees were skidded out of the treatment unit, roots were bucked off, and the stumps were then skidded back to the treatment unit. The operator also attempted to refill the stump holes, using woody debris and limbs as well as mineral soil. This extra machine movement and activity on these two treatment units was likely responsible for additional scalping and compaction, and for accumulations of woody debris, thus yielding poor planting spots. Stumps were bucked on the site for the rest of the trial and stump holes were not intentionally refilled.

The Nakusp site was harvested January to March 1996. Snow depths averaged 50 cm (compressible) during harvesting. Soils were not frozen except on the main skid trails. The harvesting methods were modified at the Nakusp site to reflect experience gained at the Golden site. Also, supervision of harvesting on the pushover treatment units at the Nakusp site was more intensive to minimize impacts related to limited operator experience. Rubber-tired skidder activity was restricted to designated trails outside of treatment units. The within-treatment unit trails were used only by small crawler-tractors or by the excavator used for pushover harvesting. Where possible, snow trails were constructed to minimize soil disturbance. Skid trails were cross-ditched, but not rehabilitated, at the Nakusp site.

FIELD METHODS

Soil disturbance measurements followed the procedures outlined in *Forest Practice Code of British Columbia, Soil Conservation Surveys Guidebook, January 1997* (BCMOF and BCMOE 1997). At each 1-m intercept point along the measurement transects, counted soil disturbance and forest floor displacement information were recorded. In addition, sample points with stump holes were described by classes for size, depth to plantable material in the stump hole, and type of fill material in the stump hole. At sample points with deposits of soil and woody debris, type and depth were noted, including deposits

in stump holes. Each sample point on the Golden site was tested for strongly calcareous mineral soil deposits, using 10% HCl.

DATA ANALYSIS

An analysis of variance (ANOVA) was used to compare the factors of harvest method and level of basal area retention, on both sites, and then on each site independently. All harvested treatment units were assessed to see if they met the guidelines for counted soil disturbance and forest floor displacement. For each site, frequencies were calculated for each disturbance category (e.g. wide gouges 3%) to develop a "disturbance profile" for each unit. Summary statistics were also calculated for stump hole size classes, depth to plantable fill material in stump holes, type of stump hole fill material, depth of deposits, and type of surface deposits.

RESULTS AND DISCUSSION

Soil Disturbance

Based on the site sensitivities for both study sites, the *Forest Practices Code of British Columbia, Soil Conservation Guidebook, April 1995* (BCMOF and BCMOE 1995) recommends an allowable dispersed soil disturbance level of 10%. The Pre-Harvest Silviculture Prescriptions (PHSP) for both sites specified a maximum allowable disturbance level of 25% for the pushover treatment units. The practice of allowing greater soil disturbance for other management objectives, including root disease treatment, is consistent with the *Soil Conservation Guidebook* (BCMOF and BCMOE 1995). Countable soil disturbance was less than 10% for all hand-felled treatments on both sites while all pushover treatments were above this value (Figure 1). Overall, counted disturbance levels were lower at the Nakusp site than at the Golden site. The values were significantly greater on all pushover treatments at Golden ($P = 0.0337$) and were greater on the pushover clearcut treatment units at Nakusp, although not statistically significant. For the pushover treatments at Golden, there was also a nonsignificant trend of greater disturbance with greater basal area removal. However, calculating the lower confidence limit (90%) for individual harvesting treatment units, which is the criteria used during a compliance audit for soil disturbance, indicates that some of the pushover treatment units achieved this lower disturbance criterion. Thus, at Nakusp, only the pushover clearcut treatment units have lower confidence limits greater than 10% (17.7-20.1%). At Golden, five of the six pushover units had lower confidence limits ranging from 20-35%. Three of these treatment units did not achieve the 25% level specified in the PHSP.

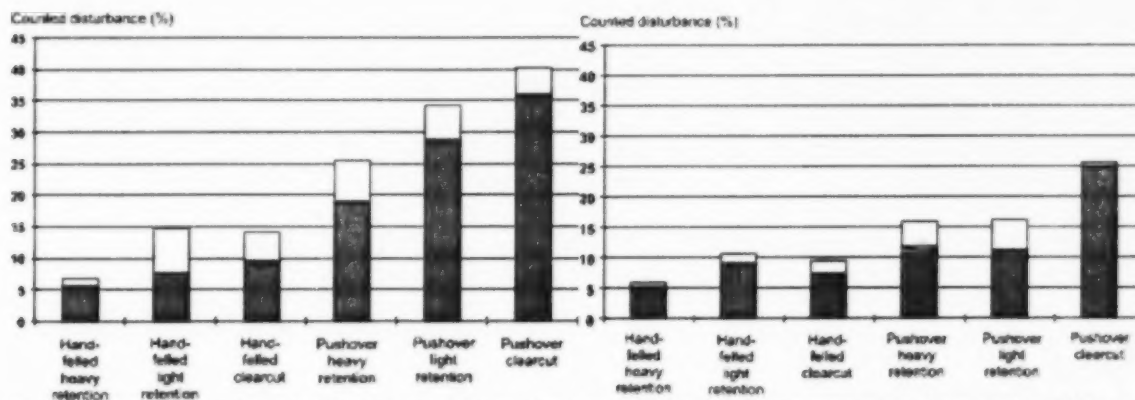


Figure 1. Soil disturbance at the Golden and Nakusp sites. The solid bar is the treatment mean, the open bar indicates the upper standard error with $n = 2$ for each treatment. Lower standard error is of equal magnitude but below mean.

Note: The FPC guideline for conventional harvesting is 10%.

Soil disturbance categories for hand-felled treatments at the Golden site were predominantly repeated machine traffic plus counted scalps and gouges (Figure 2). The pushover treatments at this site differed by having a greater percentage of wide gouges (over 80% from stump holes). Soil disturbance on the Nakusp site was dominated by the disturbance category of repeated machine traffic on both hand-felled and pushover harvested treatment units (Figure 2). Also, the pushover treatment units did have a greater area of wide gouges plus other counted gouges and scalps.

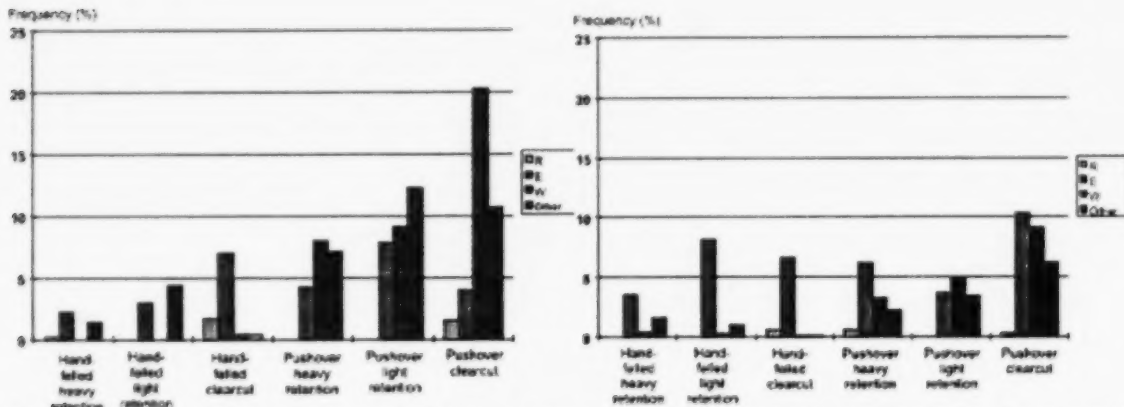


Figure 2. Soil disturbance categories at the Golden and Nakusp sites. R = excavated/bladed structures; E = repeated machine traffic; W = wide gouges, Other = wheel/track ruts plus all other countable gouges and scalps.

These results demonstrate that pushover harvesting causes more potentially detrimental soil disturbance, and for this harvesting method, the trend is for disturbance levels to be directly related to quantity of basal area removed. The differences between sites reflect reduced site sensitivities combined with modified harvesting procedures at the Nakusp site. The Golden site was rated high for compaction hazard while the Nakusp site was only rated as moderate. The more sensitive site at Golden also made it more difficult to achieve the disturbance levels specified in the PHSP. The sensitivity of this site would normally preclude stump removal (Norris et al 1998). The Golden site had greater levels of wide gouges on the pushover treatment units.

Forest Floor Displacement

The average value for all treatments was below the FPC guideline maximum of 30%, except for the pushover clearcut treatment on both sites (Figure 3). However, for individual pushover treatment units, the lower confidence limit—the standard used for a compliance audit—indicate that only three treatment units would exceed this lower value. This includes harvested treatment units for pushover clearcut at Golden (Treatment Unit 5, $LCL_{90} = 34.7\%$), pushover clearcut at Nakusp (Treatment Unit 3, $LCL_{90} = 37.7\%$), and pushover heavy shelterwood at Golden (Treatment unit 13, $LCL_{90} = 31.3\%$). These three treatment units received extra impact because of greater slope gradient or operator inexperience on the first few treatment units harvested. The generally lower levels of forest floor displacement on the Nakusp site also reflect a less sensitive site (moderate compaction hazard), improved harvesting techniques, and smaller stump sizes. Average levels for forest floor displacement at the Golden site were significantly greater for pushover harvesting than hand felled ($P = 0.009$; Figure 3). The same trend occurs at Nakusp, but is not significant ($P = 0.09$). Finally, the greatest level of forest floor displacement occurred for pushover clearcuts on both sites (Figure 3), although this is not statistically significant.

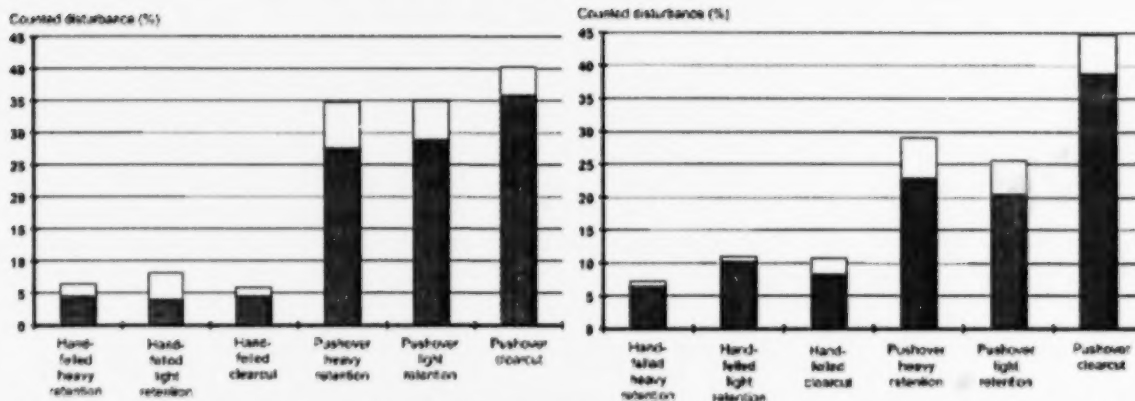


Figure 3. Forest floor displacement at the Golden and Nakusp sites. The solid bar is the treatment mean, the open bar indicates the upper standard error with $n = 2$ for each treatment. Lower standard error is of equal magnitude but below mean. Note: The FPC guideline for conventional harvesting is 30%.

Stump Holes

On both sites, most stump holes were in the largest size category ($>3.2 \text{ m}^2$). These stump holes caused a large increase in counted soil disturbance (wide gouge category, Figure 2).

The clearcut pushover treatment units at the Golden site averaged 33.1% of the area in stump holes, compared to only 22.7% for the Nakusp site. These values are greater than the 5.1-19.6% area occupied by stump holes found by Davis and Wells (1994) while surveying 19 treatment units with stump removal. The larger area of stump holes on the Golden site was primarily due to large Douglas-fir (*Pseudotsuga menziesii*) trees as compared to the smaller western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) trees at the Nakusp site.

The finer textured soil at the Golden site tended to stay on the root system, thus increasing the size and frequency of the stump holes. The coarser textured soil at the Nakusp site readily fell off the roots and into the stump hole while trees were being pushed over.

On pushover treatment units at the Golden site, depth to plantable material was 15 cm or less for over 62% of the area of the stump holes. Many stump holes on this site also had compressed woody fill materials $>15 \text{ cm}$ thick. The occurrence of these unplantable woody deposits ranged from 19% of the area occupied by stump holes on the heavy retention pushover treatment, to 41% of the stump holes on the clearcut pushover treatment.

Strongly calcareous mineral soil occurred at 41% or more of the area covered by the stump holes in the pushover treatment units. In contrast, on the Nakusp site, 89% or more of the stump holes were filled with mineral soil, without significant woody debris. Also, this latter site was noncalcareous. Exposed mineral soils are favourable for planting if they consist of fertile, upper mineral horizons.

Thus, when the two sites are compared, stump holes at the Golden site cover a greater proportion of the area, have a greater proportion of woody debris accumulations, and have exposed mineral material that is often strongly calcareous.

Deposits

Pushover harvesting also causes mineral soil or woody debris to get deposited on undisturbed surfaces or in the stump holes. At the Golden site, deposits occurred on 19-34% of the area of pushover treatment units, including stump holes, compared to only 5-13% of the hand-felled treatment units. On the clearcut treatment units, 41% of the deposits were strongly calcareous material and another 25% of the deposits were nonplantable woody debris greater than 15 cm deep. Many of these deposits were found on relatively undisturbed soil surfaces, representing a further negative impact on the site.

Deposits had less impact on the Nakusp site. Pushover harvested treatment units at the Nakusp site had mineral soil or wood deposits on only 9-16% of the area and less than 10% of the deposits were accumulations of woody debris. Less than 2% of the hand-felled treatment units at the Nakusp site had deposits, and these were almost entirely mineral soil. This resulted in fewer deposits and probably less negative site impact at the Nakusp site.

Finally, both sites were winter harvested. Season has been observed to affect levels of woody debris on pushover sites; in general, summer-harvested treatment units have less woody debris.

Overall, plantability on the Golden site appeared to be more severely impacted by pushover harvesting. This was also the observation and experience of the planting crews.

Exposure of Calcareous Subsoils by Harvesting

Soils on the Golden site are derived from calcareous parent materials and are lime rich and alkaline. Harvesting activity such as skid-road construction, scalping, gouging, and stump removal have the potential to expose deeper calcareous horizons or to deposit these materials on the surface when soil falls off root systems.

The average frequency for calcareous sample points on the hand-felled treatment units were all <5% (Figure 4). The pushover harvested treatment units had significantly greater frequencies for free carbonates with average values of 24.9-26.2% ($P = 0.0006$). Basal area removal was neither statistically significant for calcareous sample points, nor is there any apparent trend in the data for either hand-felled or pushover harvesting. This indicates that the activity of exposing tree roots during pushover is of greater significance in exposing calcareous materials than the quantity of basal area removed. It was noted that a significant slope difference existed between the treatment units in the heavy retention treatment. Greater amounts of calcareous materials were exposed on the steeper site, due to greater area of cut and fill at skid trails, greater area of rutting between access structures, and pushover felling on a hillside.

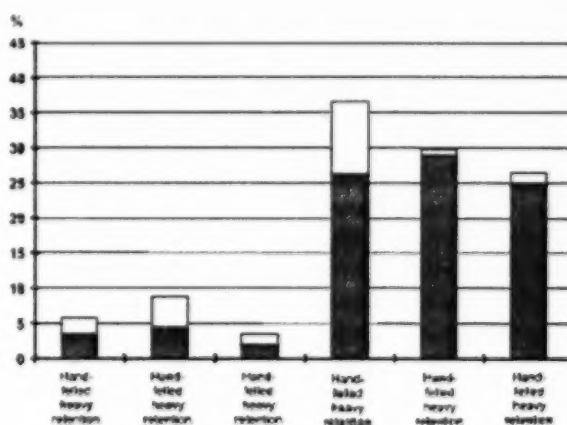


Figure 4. Calcareous sample points at the Golden site. The solid bar is the treatment mean, and the open bar indicates the upper standard error with $n = 2$ for each treatment. Lower standard error is of equal magnitude but below mean.

Agricultural researchers have long identified the adverse effects of calcareous soils on the availability of

nutrients such as phosphorus, boron, iron, and zinc (Russell 1973; Brady 1974). Smith and Wass (1994) have demonstrated the reduced height and volume growth of Douglas-fir and lodgepole pine (*Pinus contorta*) trees planted after stump removal on moderately to strongly effervescent soils near Golden. The authors of the present study observed that the deeper horizons on Mount 7 have low levels of organic matter, strongly cemented layers, and higher densities than the surface horizons. The combined effect of negative fertility and adverse physical properties of the freshly exposed calcareous soil horizons is expected to affect tree growth on the Golden site.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

At both sites, pushover harvesting caused a significantly greater level of counted soil disturbance and forest floor displacement than hand felling combined with ground skidding. There was an increase in both disturbance measures as greater basal area was removed. The combined effect of harvesting method and basal area removal was to yield maximum soil disturbance and forest floor displacement levels on the clearcut pushover treatment; at the Golden site, levels averaged 36% for both variables. Pushover harvesting at the Golden site caused a significantly greater exposure of calcareous soil materials than hand felling. Pushover treatment units averaged over 25% calcareous sample points compared to less than 5% on the hand-felled treatment units.

Pushover harvesting at Golden yielded a greater proportion of the treatment units occupied by stump holes than at the Nakusp site. This result is attributed to smaller tree size and slightly coarser soil textures at the Nakusp site. At the Golden site, a high percentage of the stump holes had exposed calcareous soil layers, calcareous deposits, or accumulations of woody debris. Pushover harvesting at the Nakusp site created stump holes with few accumulations of woody debris, fewer deposits than the other site, and deposits that were mostly mineral soil. The Nakusp site had noncalcareous soils and the Golden site was outside the recommended site conditions for root removal treatments.

The soil disturbance results support the Regional soil conservation guidelines for application of root removal on sites that meet the site sensitivity criteria for root removal (Norris et al 1998). The effectiveness of this treatment for addressing root disease is being tested in another part of the study. The soil disturbance results also support the site sensitivity criteria of the guidelines. This includes: avoiding pushover harvesting on soils with strongly calcareous parent materials, on soils with finer textures, and on slopes >30%. Also, root removal on sites with smaller trees would reduce counted soil disturbance for wide gouges and wide scalps but may require greater off-trail random skidding or more excavator hoe forwarding from the machine to the trails. Finally, on sites with soil hazards that are marginally acceptable for stump removal, the larger stumps should be left in the ground.

These research results also provide support for a number of recommendations for areas where a root removal treatment is considered desirable for tree growth.

1. Designated skid trails with post-harvest rehabilitation should be used. This practice is better than random skidding for controlling soil disturbance on most sites. A soil disturbance level of 15% has been achieved on pushover treatment units with designated skid trails and post-harvest rehabilitation. Modifications to this recommendation should be undertaken only when personnel have a sound understanding of the relationship between pushover harvesting and soil disturbance. Operational trials demonstrating successful modifications are strongly recommended prior to extensive application of modified procedures for pushover harvesting.

2. Avoid refilling stump holes with woody debris. In pushover operations, the tree should be pushed over, and the stump should be cut from the bole at the same location and placed in or near the stump

hole. These manoeuvres should be executed such that they have a minimum impact on soils, and so they are compatible with operator safety. Some disturbance may be compatible with site-preparation objectives, depending on the site prescription. The preferred material for refilling the stump holes is soil that can be shaken loose from the roots of the stump as the tree is being pushed over. With the possible exception of the inverted stump, do not refill the stump hole with woody debris.

3. Provide inexperienced machine operators with adequate training and supervision. On-site training and supervision are vital for minimizing the potentially detrimental effects of pushover harvesting.

4. If possible, it is preferable to conduct pushover harvesting on frozen soils, deep snow packs (>1 m), or powder-dry soils. However, these soil conditions are inconsistent and unreliable in many areas of the NFR, and appropriateness will vary between and even within sites.

A final recommendation for future study and operational trials would be to hand fell a site requiring root disease treatment, followed by stump removal as the excavator or other machine progresses off the site. It has been observed in other operations that excavator destumping results in less disturbance, provided proper machine attachments and techniques are used. The large, intact roots have significant mechanical strength and provide protection for soil on the site during harvesting. If stump removal must be done during harvesting, avoid machine traffic on the part of the treatment unit where stump removal has occurred, this helps to reduce the negative potential impacts of disturbing soil that is not supported by roots.

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